PREPRINT UCRL- 82897

Lawrence Livermore Laboratory

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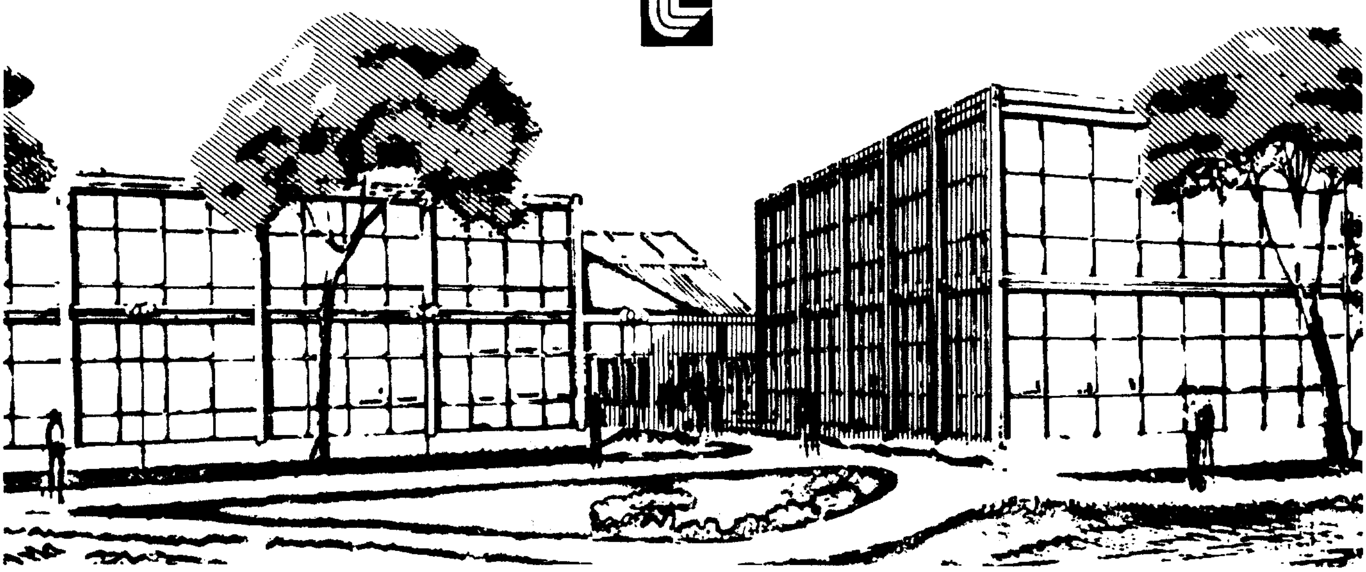
November 8, 1979

This paper was prepared for submittal to Health Physics.



DISCLAIMER

PHANTOMS FOR CALIBRATING ALBEDO NEUTRON DOSIMETERS*

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The Health Physics Society Working Group 1.5 has prepared a standard entitled "Criteria for Testing Personnel Dosimetry Performance." To determine whether this standard provides an adequate and practical test of dosimetry performance, the University of Michigan is conducting a 2-year pilot study for the U.S. Nuclear Regulatory Commission (P178). This study has been divided into eight categories involving exposures to beta rays, gamma rays, x rays, and neutrons.

During the early part of the Michigan study, some of the albedo neutron dosimeters in the neutron categories failed because of the materials used as phantoms: water, Lucite, and polyethylene phantoms of various sizes and shapes were used to calibrate the dosimeters since a standard phantom has not been established.

At the Lawrence Livermore Laboratory (LLL) we conducted a study to determine the effect of a phantom's size, shape, and composition on the response of an albedo neutron dosimeter. Hankins-type albedo dosimeters with cadmium-covered TLDs (Ha73) were exposed in air and on 15 different phantoms

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*This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore Laboratory under contract No. W-7405-Eng-48.

made of either polyethylene, Lucite, or water (Table 1). The polyethylene phantoms consisted of a 9-in. sphere, a 10-in. sphere, a 9-in.-diameter cylinder, some 4 × 4 × 4-in. cubes, an A-B remmeter (Snoopy), and five 8 × 12-in. sheets ranging from 1 to 5 in. in thickness. The Lucite phantom was a 9 × 10-in. solid block, 7 in. thick. The water phantoms consisted of a 1-gal jug, a 5-gal jug, a torso phantom* made at LLL for calibrating whole-body counters, and a duplicate of the Michigan study water phantom--a water-filled box 30 cm wide, 30 cm long, and 15 cm deep, made of 0.318-cm-thick Plexiglas.

The dosimeters were exposed to a ^{252}Cf source 1.09×10^{9} ns in the LLL low-scatter calibration facility, at a distance of 1 m (from the center of the source to the surface of the phantom). Exposure time was normalized to 1 hr. Exposures were made on the ends and sides of the polyethylene cylinder and the A-B remmeter, with the ends and sides oriented toward the source. They were made at two locations on the torso phantom--center and 2 in. off center--and at three locations on the Michigan water phantom--at the center of one of the 30 × 30-cm faces, at 90° on a 9-cm radius, and at 45° on a 9-cm radius.

Four ^{6}Li TLDs and four ^{7}Li TLDs were placed in each albedo dosimeter and the exposures on each phantom were repeated at least three times. The readings were then averaged, giving an observed coefficient of variability of ≤3%.

Neutron readings of the albedo-contained TLDs (^{6}Li minus ^{7}Li) and bare ^{6}Li minus ^{7}Li TLDs are given in Table 1 and plotted in Fig. 1, which shows the effect of polyethylene thickness on the readings. The neutron reading of

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*The torso phantom is a polyethylene bottle 18.0 cm high, 16.6 cm thick, and 27.6 cm wide. The polyethylene is 2 mm thick.

bare ^{6}Li TLDs and albedo-contained ^{6}Li TLDs is fairly constant (4.1 to 4.9) except for the exposures in air (3.3) or on the 1-in.-thick polyethylene sheet (3.0) (see Fig. 1). This ratio, however, is not the same for all exposure conditions and sources, so a bare TLD cannot be used in place of an albedo dosimeter.

The most interesting aspect of our study was the effect of geometry on the albedo readings. The readings of dosimeters exposed on the side and end of the 9-in. polyethylene cylinder increased relative to the readings of dosimeters exposed on the 9-in. polyethylene sphere by 11 and 31%, respectively. The same effect was observed for dosimeters placed on the side and end of the A-B remmeter. Obviously, the geometry of the phantom is significant in albedo dosimetry, even for very large phantoms. For example, the curved 5-gal jug gave a reading of only 134 compared to a reading of 160 for the flat 3.5-gal Michigan water phantoms.

We found no difference in the albedo readings for phantoms made of polyethylene, Lucite, or water when the geometry remained the same. For example, the readings obtained with the 3- to 5-in.-thick polyethylene sheets and at the ends of the polyethylene cylinder and the A-B remmeter were the same as the readings obtained with the Michigan water phantom and the Lucite block.

The LLL tissue-equivalent torso phantom (polyurethane based) (Gr78) was used to determine which of the phantoms was appropriate to simulate the human body. The chest wall thickness of this phantom is average for a thin person. For a person with a chest wall thickness greater than that of the phantom, the effective density and albedo readings would be correspondingly higher (on the safe side).

Figure 2 shows the location of each albedo dosimeter exposed on the torso phantom, and Table 2 shows the readings we obtained with it. The readings over the lungs (which simulate readings from a badge clipped to a shirt collar or placed in a shirt pocket) averaged 121. The readings at the center of the chest, a flat region, averaged 141 (+17%); lower readings were obtained at the sides of the phantom because the side of the chest over the lungs is curved and the effective density of the phantom is lighter at the side of the chest than it is over the heart and connecting tissue (lungs having a density of 0.3 g/cm^3, and heart and connecting tissue a density of 1.1 g/cm^3). The readings at the stomach region (which is essentially flat and has a density of about 1.1) were only slightly lower (7%) than the readings obtained with the Michigan water phantom.

Ultimately the type of phantom one uses for calibration will depend on where a person normally wears the dosimeter (clipped to his shirt collar, shirt pocket, etc.). But to be conservative, we suggest using a phantom that gives dosimeter readings similar to those obtained over the lungs.

Another problem in the early part of the Michigan study was the effect of source distance on dosimeter response. Some exposures were made with the source placed 50 cm from the phantom; others were made with the source placed 100 cm from the phantom. In the LLL low-scatter facility, the albedo neutron dosimeter response increased by 20% when the source distance was increased from 50 cm to 100 cm. The higher readings are in addition to the scatter correction factor, which is used to correct the delivered dose for the dose from scattered neutrons. The scatter correction factors applied in the Michigan study were almost identical to the ones we observed in the low-scatter facility; however, since we did not know the exposure distance, we could not correct for the change in dosimeter response caused by the change in the neutron spectra at different distances from the source.

For participation in the Michigan study, one should use a phantom that gives readings similar to those obtained with the Michigan water phantom. However, if another type of phantom is used, the appropriate correction factor should be applied. The results given in this report can be used to determine that correction factor.

ACKNOWLEDGEMENT

The author wishes to thank Carl Sundbeck for the preparation and reading of the TLDs used in this study.

REFERENCES

Ha73 Hankins D. E., 1973, "A Small, Inexpensive Albedo-Neutron Dosimeter," LA-5261, Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

Gr78 Griffith R. V., Dean P. N., Anderson A. L., and Fisher J. C., 1978, "Fabrication of a Tissue-Equivalent Torso Phantom for Intercalibration of In-Vivo Transuranic-Nuclide Counting Facilities," in Symposium on Advances in Radiation Protection Monitoring (Stockholm: IAEA).

Pl78 Plato P. and Hudson G., 1978, "Criteria for Testing Personnel Dosimetry Performance," Health Phys. **35**, 914.

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Table 1. Neutron readings of albedo-contained TLDs (^{6}Li minus ^{7}LI) and bare TLDs. All exposures were normalized to 1 hr.

Phantom	Albedo TLD reading, mR	Bare TLD reading, mR
Air	49	162
8 × 12-in. polyethylene sheet, 1 in. thick	118	368
8 × 12-in. polyethylene sheet, 2 in. thick	153	667
8 × 12-in. polyethylene sheet, 3 in. thick	159	720
8 × 12-in. polyethylene sheet, 4 in. thick	163	735
8 × 12-in. polyethylene sheet, 5 in. thick	160	760
4 × 4 × 4-in. polyethylene cubes	138	593
10-in. polyethylene sphere	126	602
9-in. polyethylene sphere	122	574
9-in. polyethylene cylinder, side	135	658
9-in. polyethylene cylinder, end	160	757
A-B remmeter, side	140	643
A-B remmeter, end	155	664
9 × 10-in. Lucite block, 7 in. thick	160	626
1-gal jug	123	570
5-gal jug	134	665
LLL torso phantom, center	153	717
LLL torso phantom, 2 in. off center	133	628
Michigan water phantom, center	158	705
Michigan water phantom, 90° on 9-cm radius	156	660
Michigan water phantom, 45° on 9-cm radius	154	667

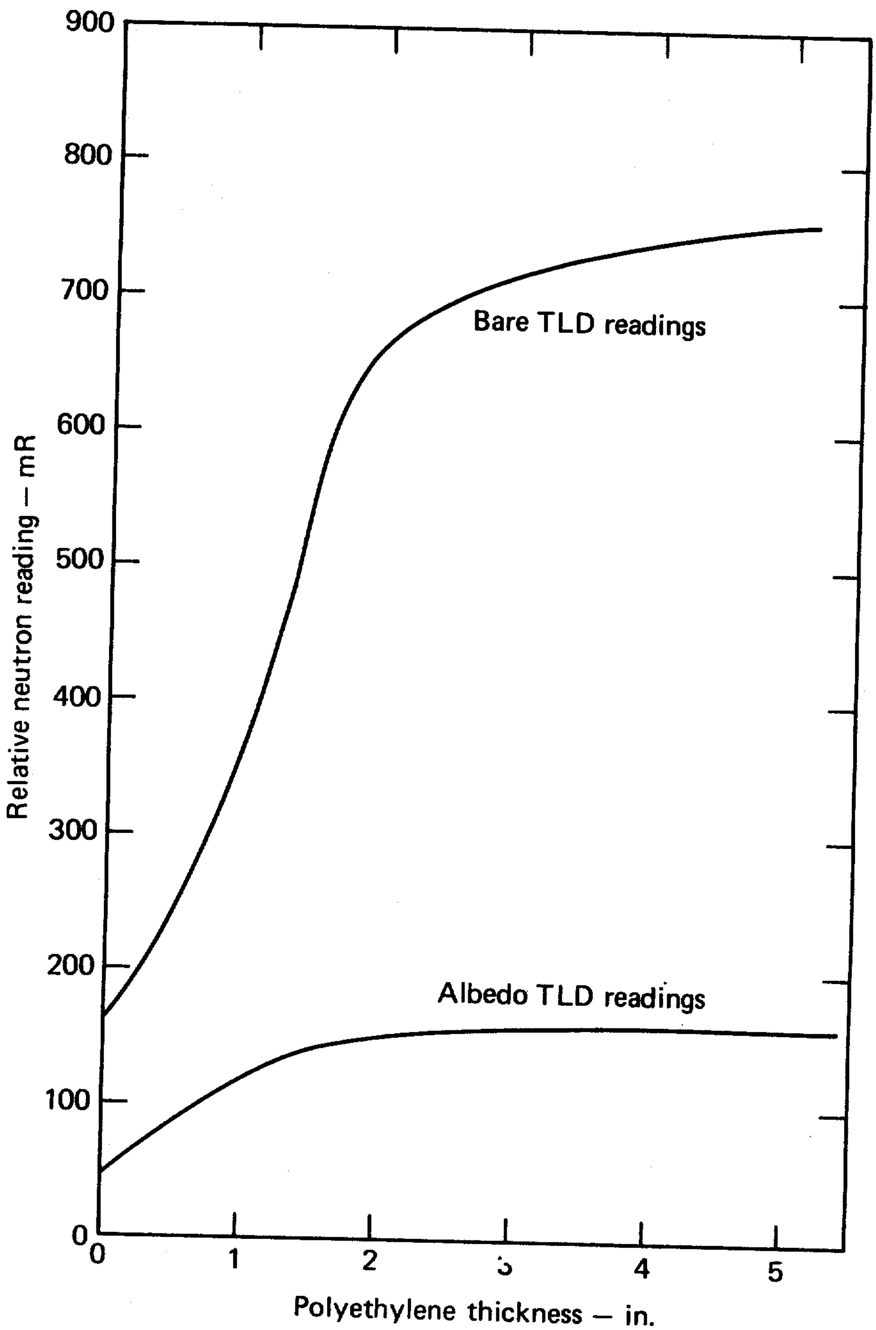
Table 2. Readings of the albedo-contained TLDs (^{6}Li minus ^{7}Li) placed at eight locations on the LLL torso phantom. These locations are shown in Fig. 2.

Location on phantom	Albedo TLD readings, mR
1	123
2	141
3	123
4	120
5	140
6	116
7	152
8	145

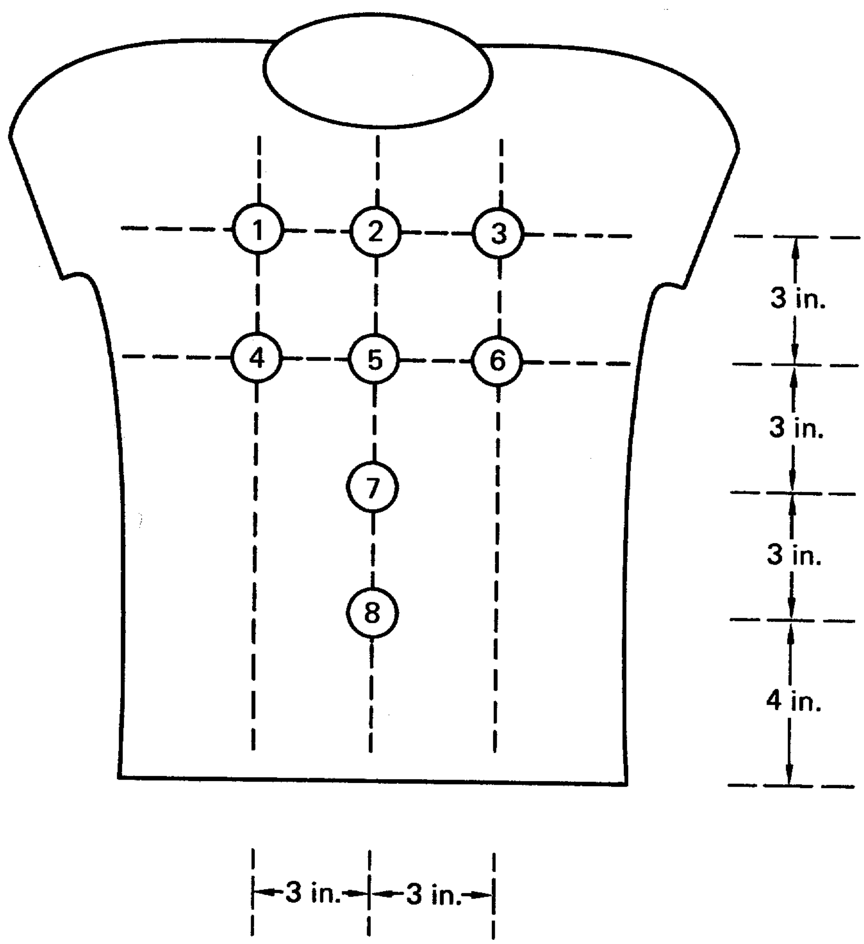
Figure captions

Fig. 1. The relative neutron response of albedo-contained TLDs (^{6}Li minus ^{7}Li) and bare TLDs placed on 8 × 12-in. polyethylene sheets ranging from 1 to 5 in. in thickness. Little additional albedo response is obtained for thicknesses greater than 2 in.

Fig. 2. Locations of albedo neutron dosimeters on the LLL torso phantom.



Hankins - Fig. 1



Hankins - Fig. 2